Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.777941

A COMPARATIVE STUDY OF MECHANICAL PROPERTIES AND MICROSTRUCTURES OF FSW JOINTS WITH CONVENTIONAL WELDED JOINTS

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Abstract:
The manufacturing functional feasibility of implementing Friction Stir Welding (FSW) technology, a highly energy-efficient solid-state joining process, for field deployable, on-site fabrications of large, complex and thick-sectioned structures of high-performance and high temperature materials. The technology innovations developed herein attempted to address two fundamental shortcomings of FSW: 1) the inability for on-site welding and 2) the inability to weld thick section steels, both of which have impeded widespread use of FSW in manufacturing. Through this work, major advance has been made toward transforming FSW technology from a "specialty" process to a mainstream material joining technology to realize its pervasive energy, environmental, and economic benefits across industry.
The technology development in this project primarily focused on its first targeted application: which combines the joining parts in the solid phase. Energy savings and environmental preservation are important issues for us to resolve. Since reducing the weight of vehicles is one of the efficient measures, the use of the combination of stainless steel 304 and bronz alloy has been increasing in fabricating vehicles. Under this situation, many trials to weld steel to bronz alloy have been conducted. However, sound joints have not been produced so far, because hard and brittle intermetallic compounds were formed at the weld whenever steel was welded to bronz by fusion welding. In gas welding process the metals get heated and due to the heating of the metal the strength of the metal decreases and also the microstructure of the metal changes. But in friction stir welding the metal gets less heated compared to the gas welding process. Due to the less heat absorbed by the metal the strength and microstructure changes comparatively less than the gas welding process. So comparatively friction stir welding gives accurate microstructure and tensile strength than the gas welding process. In the present work we tried to compare the micro structure, micro hardness and tensile strength of two Friction Stir welded joint with the gas welded joint.

1. INTRODUCTION

Friction stir welding (FSW): It is a solid-state joining process that uses a non-consumable tool to join two facing workpieces without melting the workpiece material. Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is also found in modern shipbuilding, trains, and aerospace applications.

It was invented and experimentally proven at The Welding Institute (TWI) in the UK in December 1991. TWI held patents on the process, the first being the most descriptive.

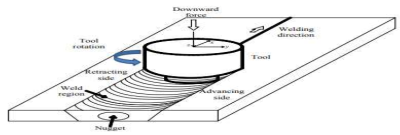
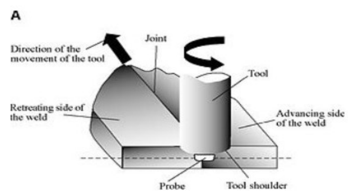
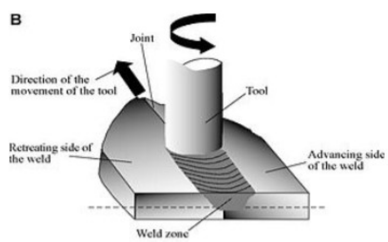


Fig. 1 – Schematic of the friction stir welding process.

1.1 Principle of operation



Two discrete metal workpieces butted together, along with the tool (with a probe)



The progress of the tool through the joint, also showing the weld zone and the region affected by the tool shoulder A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped workpieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the workpieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed.

Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the tool is moved forward, a special profile on the probe forces plasticised material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld.

This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid-state deformation involving dynamic recrystallization of the base material.

2. LITERATURE REVIEW

Muyiwa Olabode, Paul Kah and Jukka Martikainen et.al (4 March 2013): Aluminium and its alloys have gained increasing importance in structural engineering due to advantageous properties such as light weight, ease of machining and corrosion resistance. This article presents surface-related challenges facing aluminium welding, specifically weld process limitations and joint limitations. The methodological approach is a critical review of published literature and results based on eight industrial welding processes for aluminium and six joint types. It is shown that challenges such as heat input control, hot cracking, porosity and weldable thickness vary with the process used and that there is no optimal general weld process for all aluminium alloys and thicknesses. A selection table is presented to assist in selection of the optimal process for specific applications. This study illustrates that knowledge of weld limitations is valuable in selection of appropriate weld processes.

Gu¨rel C¸ am and Selcuk Mistikoglu et.al (April 8, 2014): The diversity and never-ending desire for a better life standard result in a continuous development of the existing manufacturing technologies. In line with these developments in the existing production technologies the demand for more complex products increases, which also stimulates new approaches in production routes of such products, e.g., novel welding procedures. For instance, the friction stir welding (FSW) technology, developed for joining difficult-to-weld Al-alloys, has been implemented by industry in manufacturing of several products. There are also numerous attempts to apply this method to other materials beyond Al-alloys. However, the process has not yet been implemented by industry for joining these materials with the exception of some limited applications. The microstructures and mechanical properties of friction stir welded Al-alloys existing in the open literature will be discussed in detail in this review. The correlations between weld parameters used during FSW and the microstructures evolved in the weld region and thus mechanical properties of the joints produced will be highlighted. However, the modeling studies, material flow, texture formation and developments in tool design are out of the scope of this work as well as the other variants of this technology, such as friction stir spot welding (FSSW).

Mingshen Li, Chaoqun Zhang, Dayong Wang, Li Zhou, Daniel Wellmann, and Yingtao Tian, et.al (26 December 2019): Aluminum (Al) and copper (Cu) have been widely used in many industrial fields thanks to their good plasticity, high thermal conductivity and excellent electrical conductivity. An effective joining of dissimilar Al and Cu materials can make full use of the special characteristics of these two metals. Friction stirs spot welding (FSSW), as an efficient solid-state welding method suitable for joining of dissimilar metal materials, has great prospects in future industrial applications. In this paper, the FSSW studies on Al-Cu dissimilar materials are reviewed. The research progress and current status of Al-Cu FSSW are reviewed with respect to tool features, macroscopic characteristics of welded joints, microstructures, defects in welds and mechanical properties of joints. In addition, some suggestions on further study are put forward in order to promote the development and progress of Al-Cu FSSW studies in several respects: material flow, thermal history, addition of intermediate layer, auxiliary methods and functionalization of Al-Cu FSSW joint.

V. Rajkumar, M. Venkatesh kannan, Arivazhagan Natarajan et.al (December 2017): This chapter investigates on the characterization of friction stir welded dissimilar alu-minium alloys AA2024 with AA5052, AA2024 with AA6061 and AA 5052 with AA6061. Five tool designs were employed with first two dissimilar combinations to analyze the influence of rotation and traverse speed over microstructural and mechanical proper-ties. H13 tool steel was used as tool material with various pin profiles which includes cylindrical, cylindrical- threaded, squared, tapered and stepped types. In the dissimilar welding of AA 2024 with AA 5052, sound welds were produced with stepped pin tool. In the dissimilar welding of AA 2024 with AA 6061, ratio between tool shoulder to diameter of tool pin was the most influential factor. Welded joints failed in the Heat affected zone (HAZ) of 6061 where the hardness values were comparatively less. In dissimilar welding of AA 5052 with AA6061, cylindrical pin tool was used at a constant speed of 710 rpm and at different feed rates of 28 and 40 mm/min. Micro structural examination showed varia-tion of grain size in every zone and they're influence on mechanical properties. Correlating mechanical and metallurgical properties, the optimized process parameters of speed and feed were identified to be 710 rpm and 28 mm/min respectively for all attempted dis-similar combinations.

3. CATIA

3.1 Introducing to catia:

CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

3.2 STARTING TO CATIA:

To start CATIA there may be icon on the desktop or you may have to look in start menu at the bottom of leaf of the screen windows taskbar. The program takes a while to load, so be patient the start-up is complete when your screen looks like the following figure, which is a default CATIA screen.

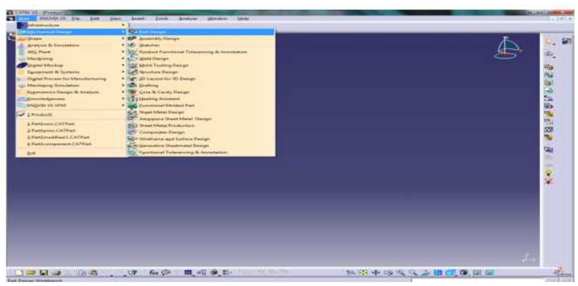


Fig 3.1: Main window and modules of Catia

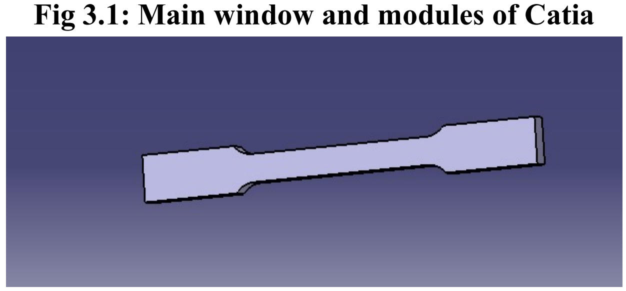


Fig 3.1: Final Assembly

4. ANSYS

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

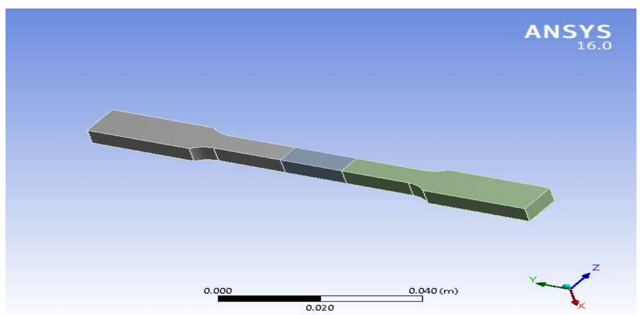
By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA may be used to help determine the design modifications to meet the new condition.

ANSYS is general-purpose finite element analysis software, which enables engineers to perform the following tasks:

1. Build computer models or transfer CAD model of structures, products, components or systems
2. Apply operating loads or other design performance conditions.
3. Study the physical responses such as stress levels, temperatures distributions or the impact of electromagnetic fields.
4. Optimize a design early in the development process to reduce production costs.
5. A typical ANSYS analysis has three distinct steps.
6. Pre-Processor (Build the Model).

4.1 ANALYSIS OF RESULTS



Material Data

AA7079

Density	2780 kg m^-3

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	7.3e+010	0.33	7.1569e+010	2.7444e+010

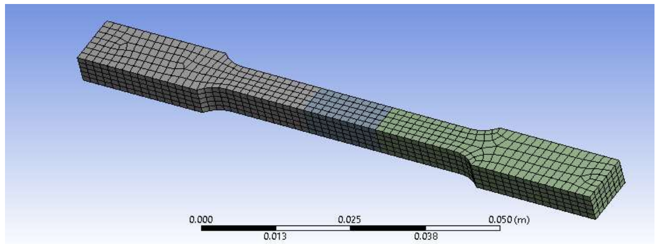
·COPPER CZ101

Density	2780 kg m^-3

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	7.3e+010	0.33	7.1569e+010	2.7444e+010

Tensile Yield Strength Pa
9.7e+007

Mesh



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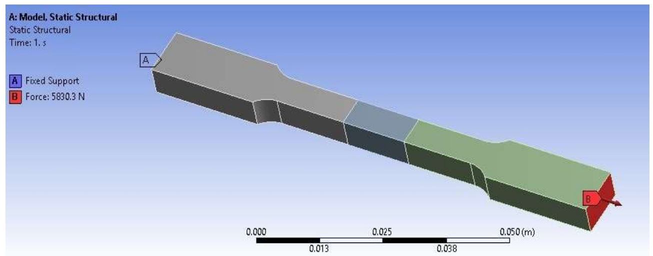


Fig 4.1: Boundary conditions

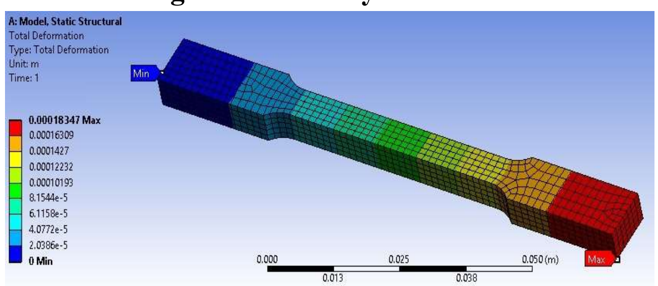


Fig 4.1: Total Deformation

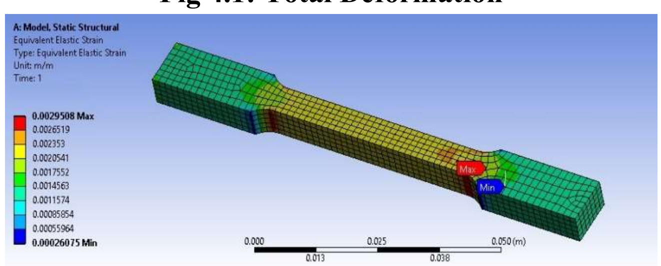


Fig 4.2: Equivalent Elastic Strain

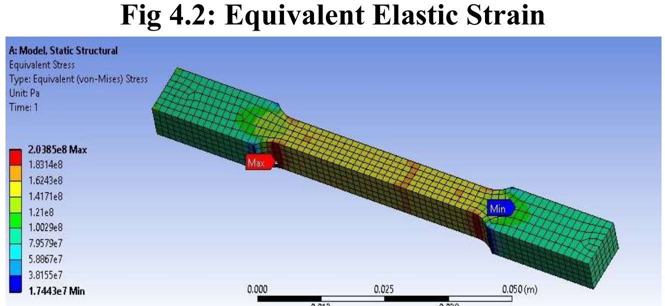


Fig 4.3: Equivalent Stress

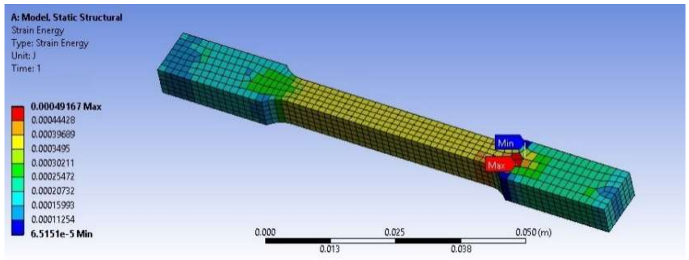


Fig 4.4: Equivalent Stress

Object Name	*Total Deformation*	*Directional Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*	*Strain Energy*
State	Solved				
Results					
Minimum	0. m	-1.8345e-004 m	2.6075e-004 m/m	1.7443e+007 Pa	6.5151e-005 J
Maximum	1.8347e-004 m	0. m	2.9508e-003 m/m	2.0385e+008 Pa	4.9167e-004 J
Minimum Occurs On	Part Body				
Maximum Occurs On	Part Body				
Information					
Time	1. s				
Load Step	1				

Table 4.1: results

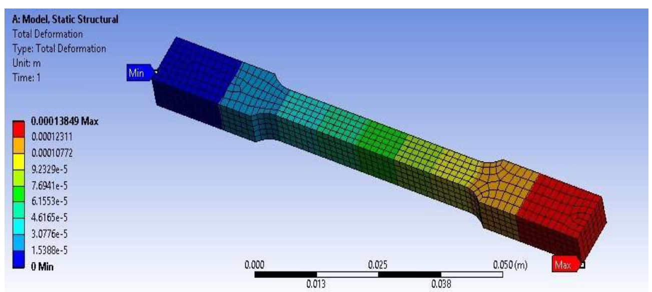


Fig 4.5: Total Deformation

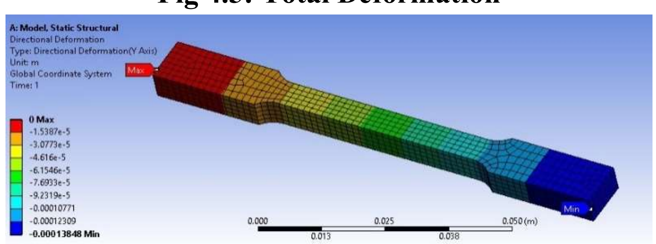


Fig 4.6: Directional Deformation

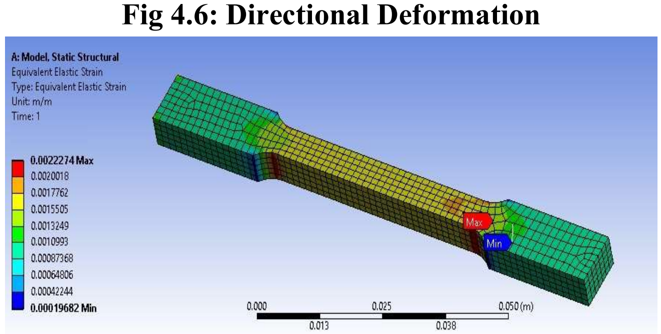


Fig 4.7: Equivalent Elastic Strain

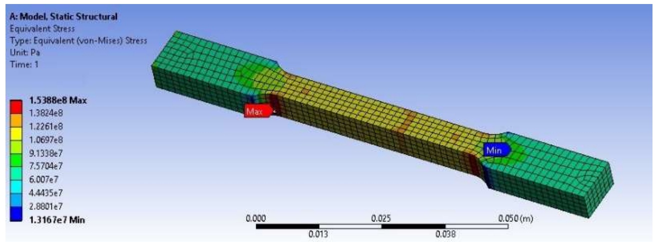


Fig 4.8: Equivalent Stress

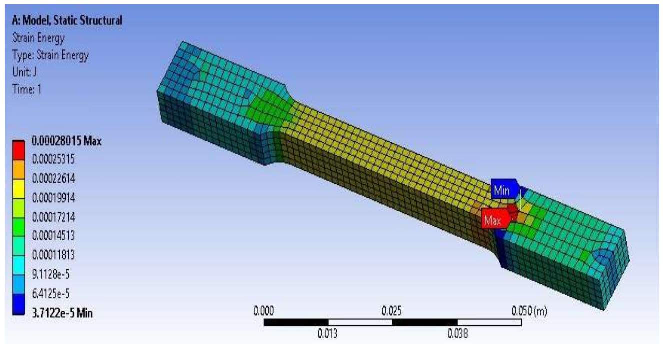


Fig 4.8: Strain Energy

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress	Strain Energy
State	Solved				
Results					
Minimum	0. m	-1.3848e-004 m	1.9682e-004 m/m	1.3167e+007 Pa	3.7122e-005 J
Maximum	1.3849e-004 m	0. m	2.2274e-003 m/m	1.5388e+008 Pa	2.8015e-004 J
Minimum Occurs On	PartBody				
Maximum Occurs On	PartBody				
Information					
Time	1. s				
Load Step	1				

Table 4.2: results

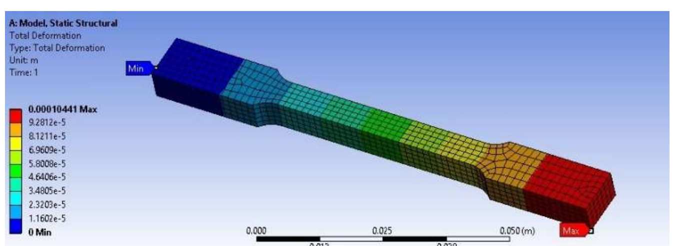


Fig 4.9: Total Deformation

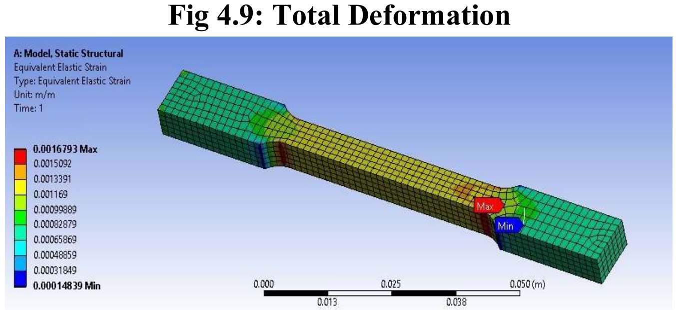


Fig 4.10: Equivalent Elastic Strain

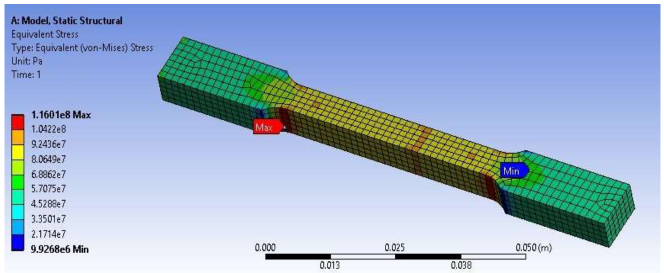


Fig 4.11: Equivalent Stress

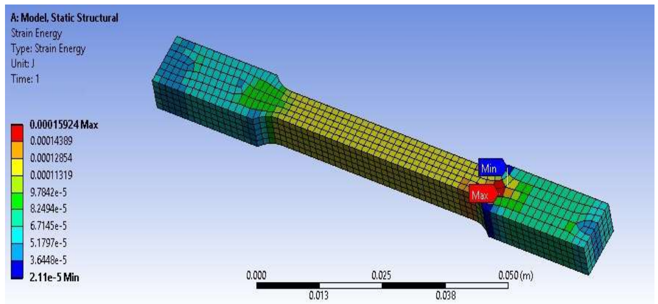


Fig 4.12: Strain Energy

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress	Strain Energy
State	Solved				
Results					
Minimum	0. m	-1.044e-004 m	1.4839e-004 m/m	9.9268e+006 Pa	2.11e-005 J
Maximum	1.0441e-004 m	0. m	1.6793e-003 m/m	1.1601e+008 Pa	1.5924e-004 J
Minimum Occurs On	PartBody				
Maximum Occurs On	PartBody				
Information					
Time	1. s				
Load Step	1				

Table 4.3: results

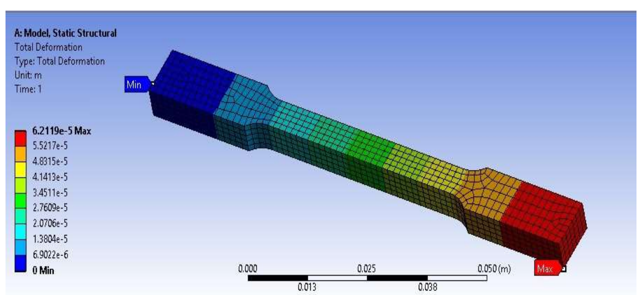


Fig 4.13: Total Deformation

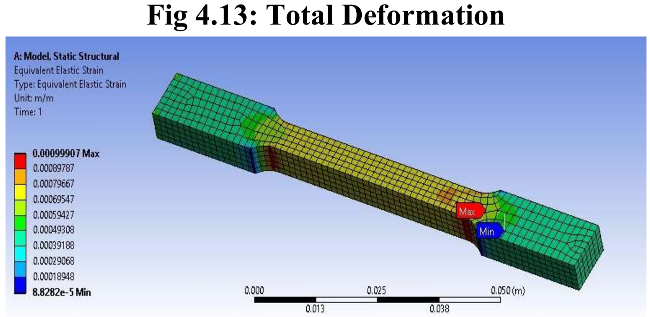


Fig 4.14: Equivalent Elastic Strain

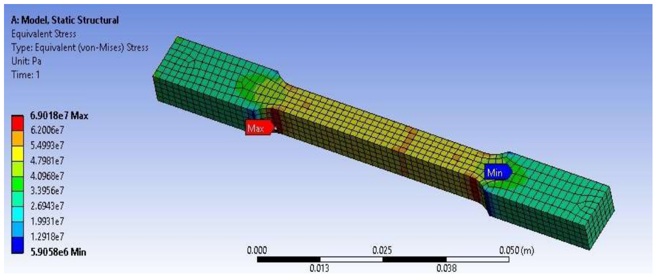


Fig 4.15: Equivalent Stress

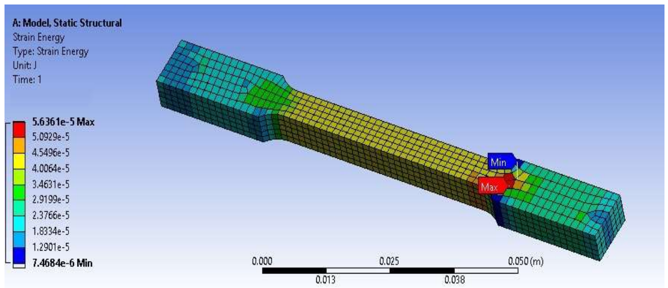
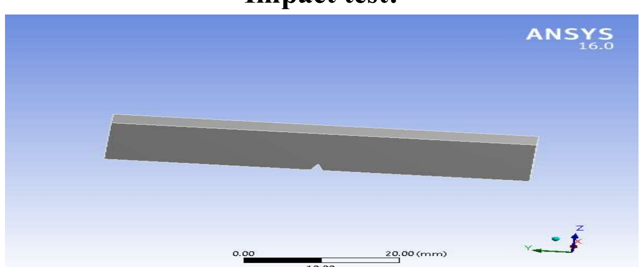


Fig 4.15: Strain Energy

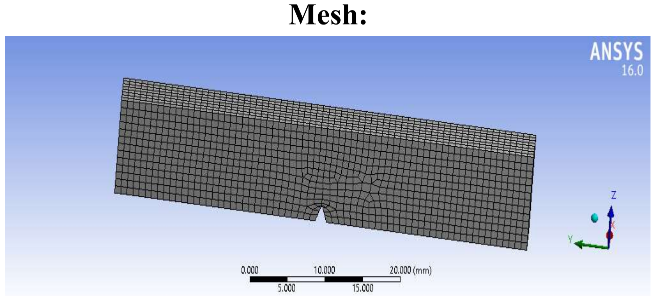
Object Name	*Total Deformation*	*Directional Deformation*	*Equivalent Elastic Strain*	*Equivalent Stress*	*Strain Energy*
State	Solved				
Results					
Minimum	0. m	-6.2113e-005 m	8.8282e-005 m/m	5.9058e+006 Pa	7.4684e-006 J
Maximum	6.2119e-005 m	0. m	9.9907e-004 m/m	6.9018e+007 Pa	5.6361e-005 J
Minimum Occurs On	PartBody				
Maximum Occurs On	PartBody				
Information					
Time	1. s				
Load Step	1				

Table 4.4: results

Impact test:



Mesh:



Loads:

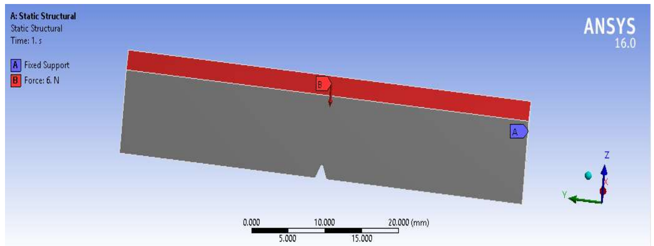


Fig4.16: Boundary conditions

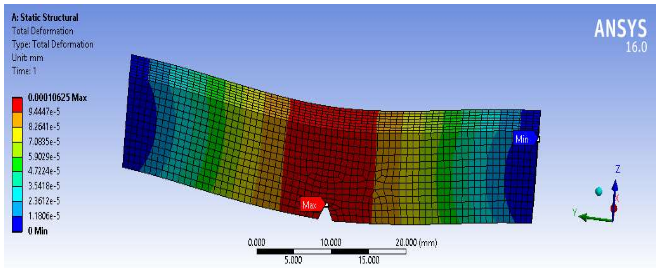


Fig4.17: Total Deformation

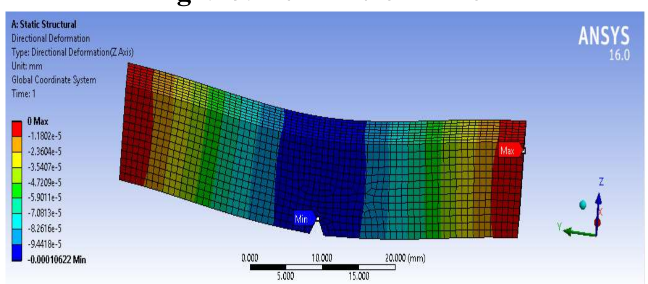


Fig4.17: Directional Deformation

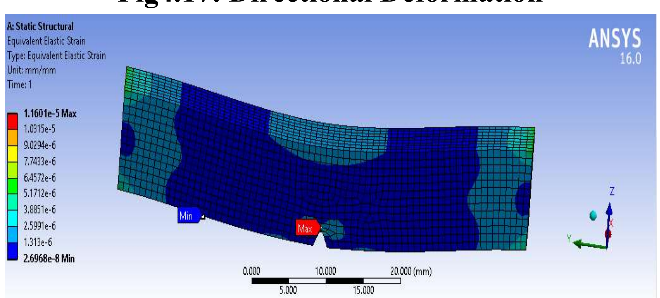


Fig4.18: Equivalent Elastic Strain

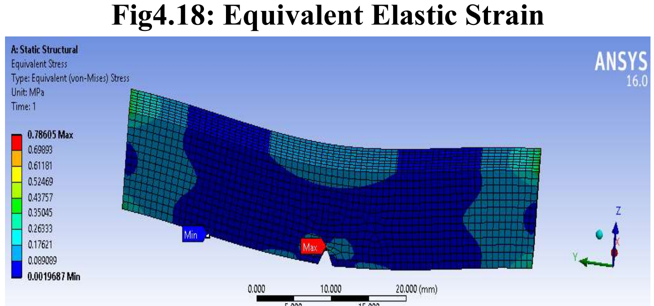


Fig4.19: Equivalent Stress

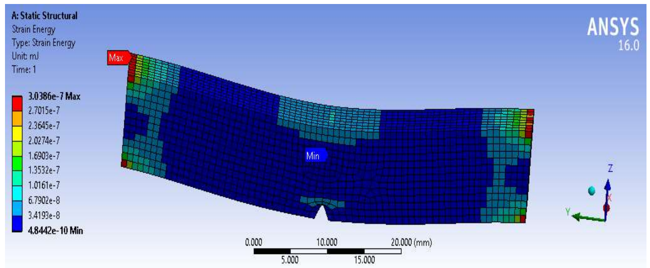


Fig4.20: Strain Energy

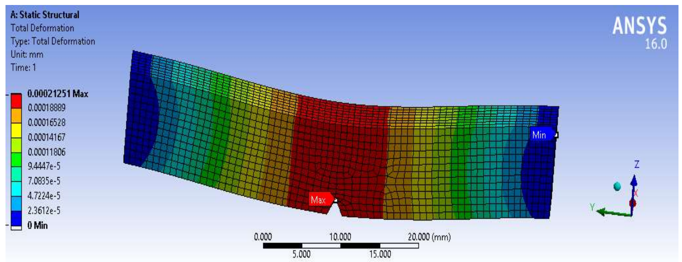


Fig4.21: Total Deformation

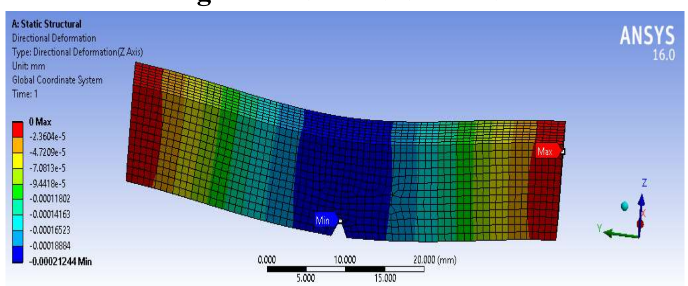


Fig4.22: Directional Deformation

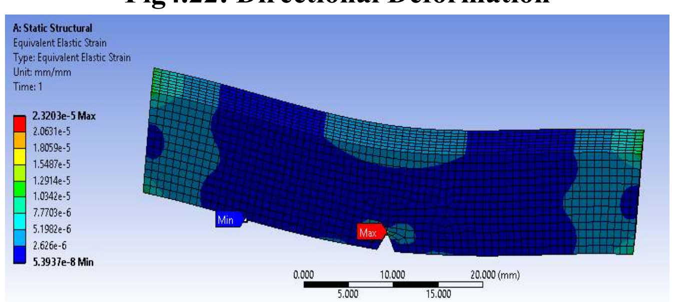


Fig4.22: Equivalent Elastic Strain

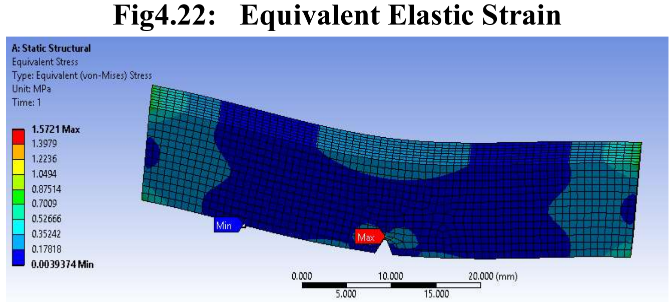


Fig4.23: Equivalent Stress

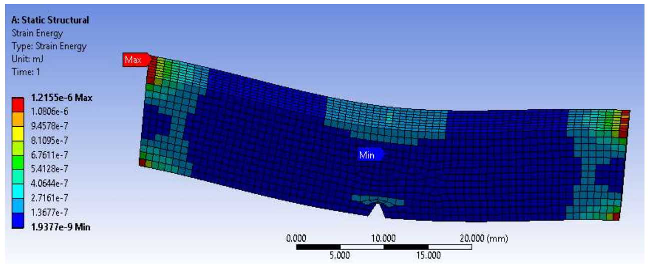


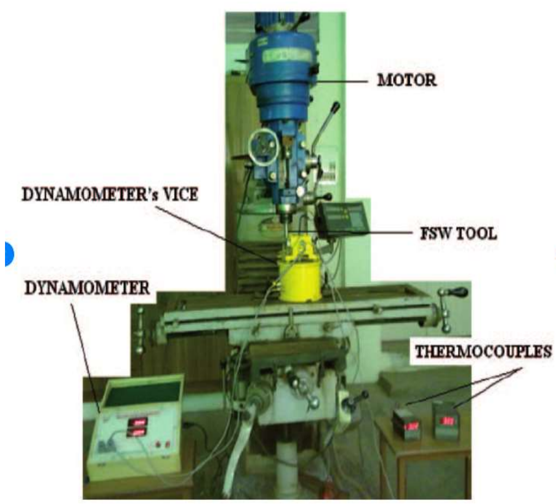
Fig4.24: Strain Energy

Object Name	Total Deformation	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress	Strain Energy
State	Solved				
Results					
Minimum	0. mm	-1.0622e-004 mm	2.6968e-008 mm/mm	1.9687e-003 MPa	4.8442e-010 mJ
Maximum	1.0625e-004 mm	0. mm	1.1601e-005 mm/mm	0.78605 MPa	3.0386e-007 mJ
Information					
Time	1. s				
Load Step	1				

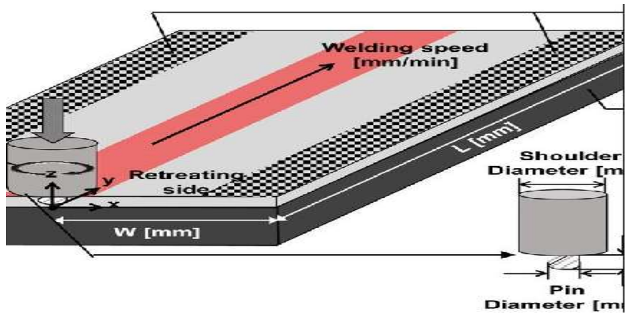
Table 4.5: results

5. Experimental procedure:

Friction Stir Welding (FSW) is new joining method derived from conventional welding which enables the advantages of solid state welding. This joining technique has been shown to be effective for joining aluminium alloys, magnesium, copper and other low-melting point metal1. It is technically a simple process where a non-consumable rotating tool with a specially designed pin profile and shoulder is inserted into the abutting edges of metal sheets or plates to be joined and traversed along the line of joint1,2 as shown in Fig. 1. As the process goes, the non-consumable rotating tool generate frictional heat to the material causing intense plastic deformation at elevated temperatures, resulting a good quality of welding as well as fine microstructure properties thus produces good mechanical properties



Experimental setup of FSW. FSW: friction stir welding.



Following are the tests carried out to check the mechanical properties of LM6 –Titanium boron (LM6-Ti-B) metal matrix composites.

TENSILE TEST

The fracture result as shown in Fig. 10, obtained is very much influenced by the welding parameter. From the result shows that FSW1 and FSW3 fractured on retreating side. This could lead due to incompatibility of combination on transverse and rotational speed for these particular samples thus fractured on retreating side.

Tensile strength is a measurement of the force required to pull something to the point before it breaks .Tensile test was done using Universal Testing Machine (UTM) fig 2. The Specimen used as per ASTM E8 standard. The specimen made of FSW metal matrix composites having 20% is used for tensile test . Fig 3 (a) and (b) shows the specimens before and after tensile testing.

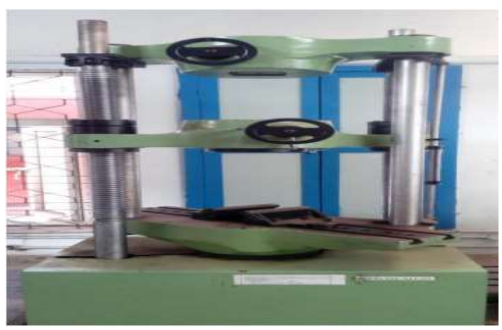
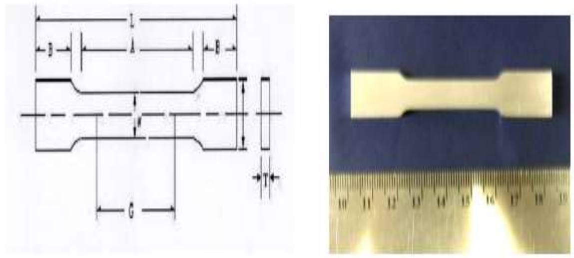
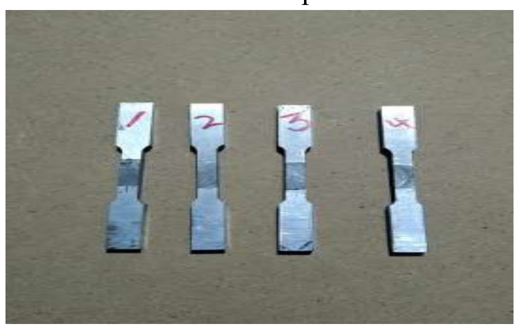


Fig:2 Universal Testing Machine

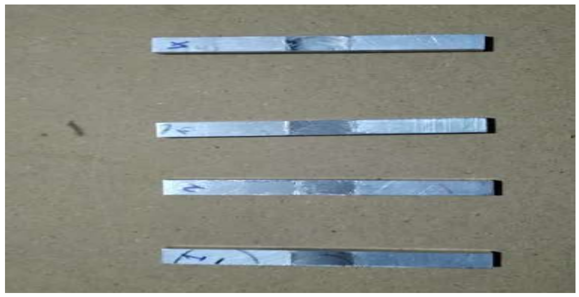


G-Gage length: 25±0.1mm W-Width: 6±0.1mm
T-Thickness 6±0.1mm R-Radius of fillet, min: 6mm
L-Overall length, min: 100 mm: A-Length of reduced section: 32mm
B-Length of grip section, min: 30 mm C-Width of grip section: 10mm
Figure 3-5 Schematic illustration of Tensile Test Specimen & machine.



impact testing

Macro hardness measurements were conducted on the polished AM60 matrix alloy and composites. The Rockwell F scale was used for macro hardness measurement in accordance with ASTM E18-94 standard for both the matrix alloy and composites. Figure 3-6 the macro hardness testing equipment which is Wilson M1CI mode of Rockwell hardness tester.



Conclusion:

In the present study, within the range of experimental conditions, the following conclusions are made, which can be useful for Friction stir welding of circular butt weld joint between Aluminium alloy AA7075 and COPPER CZ101.

AL 7075 and COPPER CZ101 can be welded using FSW by proper selection of tool pin profile and welding parameters.

Different tool designs and specifications affect the appearance as well as properties of welded joint as the way of welding is round about, more troubles have been confronted contrasted with direct way welding.

The most compelling parameters were observed during FSW process rotational speed of 1150 rpm and welding speed of 10 mm/min were observed to be the most compelling parameters, influencing mechanical properties of roundabout butt weld joint amongst AA7075 and COPPER CZ101 when welded by utilizing tube shaped strung pin device ofH13 material. The trials that lower estimations of Tool rotational speed and welding speed are better for FSW of unique compounds under thought when utilizing HCHCr device material.

REFERENCES

[1] Mohandoss T, Madhusudhanan reddy G (1996) Effect of frequency of pulsing in gas tungsten arc welding on the microstructure and mechanical properties of titanium alloy welds. J Matar Sci Lett 15:626-628.

[2] Larson, H,. Karlsson L " A Welding Review", Vol 54 No 2 ESAB AB, Sweden, PP 6-10,2000.

[3] H.J. Liu, H. Fuiji, M. Maeda, K, Nogi. 2003. Tensile properties and fracture locations of friction-stir welded joints of 6061-T6 aluminium Alloy. Mater. Sci. Lett. P.22.

[4] Muhsin J.J., Moneer.H, Tolephih and Muhammed.A.M., Effect of Friction Stir Welding parameters (Rotation and Transverse) speed on the transient temperature distribution in FSW of AA 7020-T53. ARPN Journal of Engineering and Applied science Vol7, 2012.

[5] Munoz C, Ruckert G (2004) comparision of TIG welded and Friction stir welded Al-4.5 Mg-0.26 Sc alloy. J.Matar process Technol 152:97-105.

[6] Peel M, Steuwer A, Preuss M, Withers PJ. Microstructure, mechanical properties and residual stresses as a function of welding speed in AA5083 friction stir welds. Acta Mater 2003;51:4791–801.

[7] Chen CM, Kovacevic R. Finite element modeling of friction stir welding– thermal and thermomechanical analysis. J Mach Tools Manuf 2003;43:1319–2

[8] Schmidt H, Hattel J, Wert J. An analytical model for the heat generation in friction stir welding. Mater Sci Eng 2004;12:143–57.